Broadband Forum response to FCC National Broadband Task Force request for information regarding broadband access technology capabilities

0.0 The Broadband Forum

The Broadband Forum mission is to develop the full potential of broadband in cooperation with Standards Developing Organizations such as ITU-T, ATIS and IEEE[1]. Following its union with the IP/MPLS Forum, the Broadband Forum is now the central body for next generation IP network specifications. This organization, established in 1994 and comprising of around 200 members of most of the world's leading service providers (both large and small), equipment manufacturers, chip vendors and other key organizations, defines and facilitates next generation networks for local broadband access, mobile backhaul, business services, IPTV, gaming and other applications, and is poised to address further developments as they arise. While the Broadband Forum is a global industry organization, this paper addresses solely broadband access situation for the United States. The situation in other countries may be very different. The Broadband Forum's formal BroadbandSuite™ Release Program, Technical Reports, Marketing Reports (white papers)[2] and specifications are publicly available at www.broadband-forum.org.

The Broadband Forum has collected input from its membership to provide an overview of the performance of various broadband technologies with the aim of providing the FCC with a thorough analysis of the capabilities of the technologies in reaching the US population in the most cost-effective manner. As the Broadband Forum is governed under US anti-trust regulations we cannot quote specific US$ figures; however we have provided relative cost comparisons in a generic format.

1.0 Introduction

In general, the cost to provide broadband access increases with the bit-rate capacity of the access because of the need to take fiber closer to the periphery of the access network. As the bit-rate increases, the construction cost increases with the increased miles of new fiber optic lines and a larger extent of remote equipment. The increased traffic drives up the core and aggregation network costs. Also, higher bit-rate capacity tends to increase the per line consumption of electrical energy. In some cases, the cost to deliver 100 Mb/s may be more than ten times the cost to deliver 1 Mb/s.

The cost to provide broadband access to a subscriber also depends on service take-rate, franchise fees, housing density, local geography, and whether the local area has existing housing (brownfield) or is new-build (greenfield). For the same bit-rate, the cost per subscriber in some areas may be more than one hundred times the cost of other areas.

There is a portion of the US population that resides in areas where it would not be economic for a service provider in current circumstances, to provide broadband service. Assuming no other incentive, broadband service providers rarely provide service in areas that are uneconomic. As the bit-rate capacity of the broadband access increases, the proportion of population that may be profitably served decreases. A mosaic of access methods is available to address this trade-off between bit-rate and coverage.

Subsidies could increase the size of the population that may be profitably served, but the amount of subsidy would become extremely large to achieve 50+ Mb/s service to nearly all homes. Subsidies would potentially have a much greater coverage impact if applied to expanding the availability of broadband access at up to 1 Mb/s. In this paper, no subsidies beyond the current establish practice is assumed.

Currently, areas with high subscriber density tend to have high bit-rate service, medium density areas have medium bit-rate service, and lower density areas have lower bit rate or no broadband service. Of course, other aspects such as aerial vs.

[1] ITU-T - International Telecommunication Union. ATIS - Alliance for Telecommunications Industry Solutions. IEEE – Institute of Electrical and Electronics Engineers.

[2] The Broadband Forum has several white papers available that could be of interest to the FCC: MR (Marketing Report)-001 DSL Anywhere Issue 2(2004), MR-185 Next Generation Broadband Access (2009), MR-204 Energy Efficiency, Dematerialization and the role of the Broadband Forum (2009) and MR-186 BroadbandSuite 3.0 Companion Guide (2009).

buried plant and maturity of technology are also factors. Recent advances in DSL technology enable the profitable provision of high bit-rate access to many more areas.

Fiber-like bit-rates and quality-of-service can be provided by VDSL2 technology (utilizing fiber to the curb or node – FTTC/N) to a large portion of the homes which are too costly to serve via fiber to the home (FTTH). An even larger proportion of homes may be profitably served at 6 Mb/s and above using ADSL2plus technology. While this bit-rate is less than FTTH, 6 Mb/s supports Internet access with all of today's popular Internet applications including at least one high-quality video stream.

Due to antitrust law, this paper does not discuss absolute costs. Instead, relative cost is discussed. To provide a meaningful comparison, this paper discusses bit-rate per subscriber, not the aggregate capacity of a shared media such as a trunk fiber, coaxial cable, or wide-area radio system. Furthermore, this paper discusses assured busy-hour bit-rate per subscriber; not a "typical" bit-rate. This may also be described as sustained bit-rate as distinguished from "peak" bit-rate that may not be realized depending on the traffic demands of a subscriber's neighbors. When considering shared bandwidth access methods such as cable or radio, one must understand what the sustained bit-rate per subscriber is.

The following broadband access methods are presented in order from the highest capacity and highest cost to the lowest capacity and lowest cost.

- FTTH (fiber to the home) 80 Mb/s or greater downstream
- FTTC/B (fiber to the curb or building) 70 Mb/s or greater downstream
- FTTN (fiber to the node) 60 Mb/s or greater downstream[3]
- FTTSA (fiber to the serving area) 6 Mb/s or greater downstream
- ADSL (asymmetric digital subscriber line fed from Central Office and some remote nodes) 700 kb/s or greater downstream

With the advent of 4G broadband wireless technologies such as LTE and WiMAX, it may also be possible to provide wireless service at rates similar to ADSL2plus in areas where wired services are just not economically or otherwise feasible (due to topography, for example). Radio (LTE, WiMAX, direct satellite) may typically provide lower bit rates and, as is the case with Fiber and DSL, the cost per subscriber may be quite high for low-density areas. Also, using broadband radio to provide consistent and sustained high bit-rates to subscribers may depend on a number of variables.

It should be noted that in some areas, the cost for FTTH may be less than or equal to the FTTC or FTTN alternatives. For example, the cost for FTTH in greenfield areas is often less than the alternatives, especially when whole-life cost is considered.

Broadband access using DOCSIS over coaxial cable is not addressed in this paper, but it is expected to be most similar to the FTTN case.

Beyond the single link methods discussed in this paper, hybrid access methods also exist. For example, a subscriber may be served with direct broadcast satellite for broadcast type services plus ADSL for two-way and unicast communication.

2.0 State of the technology in 2010

In all cases, the stated performance is based upon a set of assumptions[4] applied to residential subscribers[5], and which are moderately conservative to assure reliable service with real-world impairments. All bit-rates are net bit-rates available to convey subscriber traffic. For non-vectored VDSL2 and ADSL2plus, typical crosstalk noise was included in determining the bit-rate.

[3] In some cases, it is assumed that two-line bonding is used.
[4] 2010 best of class implementation using best performing profile for each distance 6 dB margin is assumed. 24 AWG wire is assumed, with no bridged taps and no inside wire. Performance with 22 AWG, which is often used in rural areas, would yield higher bit rates.
[5] Business services have not been factored into the calculations for this paper

The bit-rates are statistically conservative values[6] representing a distribution where the majority lines would achieve a higher bit-rate than shown and a very small number of lines with severe impairments would be less.

2.1 Fiber optics

Fiber technology is evolving from 155 Mb/s to 10 Gb/s, with systems built on standards from the ITU-T BPON (ITU-T G.983), GPON (ITU-T G.984), and NGPON (ITU-T G.987) and the IEEE (802.3-2009).

The bit-rate per subscriber depends on the split ratio having 32 to 128 subscribers sharing the following aggregate bit rates:
-BPON: 622 Mb/s downstream and 155 Mb/s upstream
-GPON: 2.488 Gb/s downstream and 1.244 Gb/s upstream
-NGPON1: 10 Gb/s downstream and 2.5 Gb/s upstream
-NGPON2: 10 Gb/s downstream and 10Gb/s upstream
-1G-EPON: 1 Gb/s downstream and 1 Gb/s upstream
-10G-EPON: 10 Gb/s downstream and either 1 Gb/s or 10 Gb/s upstream

Depending on the type of FTTH technology, the split ratio, and traffic engineering, the FTTH bit-rate per subscriber can range from 20 to over 300 Mb/s downstream and 4.8 to over 100 Mb/s upstream. Future deployments of FTTH are expected to provide at least 80 Mb/s downstream and 37 Mb/s upstream per subscriber.

FTTC/B may employ VDSL2 for the last few hundred feet to the customer.

2.2 VDSL2

VDSL2 (ITU-T G.993.2) technology conveys broadband information over telephone lines. Subscribers on short and medium lines are usually served via a single line, but subscribers on longer lines may be served by VDSL2 connected to two phone lines ("bonding") to achieve a higher bit-rate. As shown in the chart below, the achievable VDSL2 bit rate increases as the line length decreases. Recently, a VDSL2 transmission technique called Vectoring (draft ITU-T G993.5) has been introduced to increase the bit-rate by canceling most of the crosstalk between the VDSL2 lines sharing the same binder. Vectored VDSL2 equipment exists today and it will be available from several vendors in 2010 (these vendors have authored various informational white-papers that may be useful to the FCC in further studying the current and future capabilities of vectoring).

Per-subscriber bit-rates for a single vectored VDSL2 line and two-line bonding are shown in the following tables[7][8]:

Vectored VDSL2 SINGLE LINE per subscriber

Configuration with-	Line length	Vectored downstream bit-rate for single line	Vectored upstream bit-rate for single line
FTTC or FTTN	300 feet	160 Mb/s	63 Mb/s
FTTC or FTTN	600 feet	160 Mb/s	63 Mb/s
FTTN	1,200 feet	150 Mb/s	63 Mb/s
FTTN	3,000 feet	45 Mb/s	9 Mb/s
FTTN	4,000 feet	40 Mb/s	8 Mb/s
FTTN	4,500 feet	36 Mb/s	5 Mb/s
FTTN	5,000 feet	30 Mb/s	3 Mb/s

[6] The bit rates listed are for general guidance. Broadband Forum approved performance requirements on DSL are addressed in TR (Technical Report)-100 and TR-114.
[7] Future implementations are expected to increase the bit rates for lines shorter than 1,000 feet.
[8] The data contained in the tables for VDSL2 and ADSL2plus using the same profile (see Note 4) are presented in a graphical and expanded format in Appendix A.

Vectored VDSL2 TWO-LINE BONDING

Configuration with-	Line length	Vectored downstream bit-rate for two-line bonding	Vectored upstream bit-rate for two-line bonding
FTTC or FTTN	300 feet	320 Mb/s	126 Mb/s
FTTC or FTTN	600 feet	320 Mb/s	126 Mb/s
FTTN	1,200 feet	300 Mb/s	126 Mb/s
FTTN	3,000 feet	90 Mb/s	18 Mb/s
FTTN	4,000 feet	80 Mb/s	16 Mb/s
FTTN	4,500 feet	72 Mb/s	10 Mb/s
FTTN	5,000 feet	60 Mb/s	6 Mb/s

Note that VDSL2 FTTN may be efficiently employed with a single line serving subscribers on shorter lines and two-line bonding used only for the longer lines.

VDSL2 per-subscriber bit-rates with Level-1 dynamic spectrum management (no vectoring) using one line are shown in the following table[9]:

Single line VDSL2 (without vectoring)

Configuration with-	Line length	Downstream bit-rate	Upstream bit-rate
FTTC or FTTN	300 feet	90 Mb/s	40 Mb/s
FTTC or FTTN	600 feet	80 Mb/s	35 Mb/s
FTTN	1,200 feet	70 Mb/s	30 Mb/s
FTTN	3,000 feet	35 M/bs	6 Mb/s
FTTN	4,000 feet	30 Mb/s	5 Mb/s
FTTN	4,500 feet	24 Mb/s	4 Mb/s
FTTN	5,000 feet	20 Mb/s	2 Mb/s

VDSL2 per-subscriber bit-rates without Level-1 Dynamic Spectrum Management (DSM Level 1) using one line (and no vectoring) are shown in the following table:

Single line VDSL2 (without DSM Level 1 or vectoring)

Configuration with-	Line length	Downstream bit-rate	Upstream bit-rate
FTTC or FTTN	300 feet	90 Mb/s	40 Mb/s
FTTC or FTTN	600 feet	80 Mb/s	35 Mb/s
FTTN	1,200 feet	70 Mb/s	30 Mb/s
FTTN	3,000 feet	35 Mb/s	6 Mb/s
FTTN	4,000 feet	30 Mb/s	5 Mb/s
FTTN	4,500 feet	24 Mb/s	4 Mb/s
FTTN	5,000 feet	20 Mb/s	2 Mb/s

The bit rates realized with and without DSM Level 1 are approximately the same. Managed appropriately, VDSL2 with or without DSM Level 1 can provide high quality service. However, DSM Level 1 results in increased stability for VDSL2. The bit rate and reach for any DSL line is determined by the network operator's definition of service stability for that customer.

[9] The data contained in the tables for VDSL2 and ADSL2plus using the same profile (see Note 4) are presented in a graphical and expanded format in Appendix A.

2.3 ADSL2plus

ADSL2plus (ITU-T G.992.5) technology conveys broadband information over telephone lines longer than those used for VDSL2 technology. The following is based on a single line per subscriber, but two-lines (bonding) could be applied to double the bit-rates.

Vectoring, although possible on ADSL2plus, has not been applied to the analysis of ADSL2plus, as the benefits of the technique are most beneficial on line lengths below 4,000 feet.

Level 1 dynamic spectrum management is of benefit to ADSL2plus, particularly to enable reliable fault diagnosis, and may increase bit-rates by up to 10%, but that is not factored in the table below[10].

Single line ADSL2plus

Configuration with-	Line length	Downstream bit-rate	Upstream bit-rate
FTTSA or CO	4,000 feet	15 Mb/s	1 Mb/s
FTTSA or CO	6,000 feet	13 Mb/s	1 Mb/s
FTTSA or CO	9,000 feet	9 Mb/s	850 kb/s
FTTSA or CO	12,000 feet	6 Mb/s	800 kb/s
Central Office	18,000 feet	700 kb/s	400 kb/s

3.0 Estimated coverage for each broadband access method

The broadband coverage estimates reflect the combined opinions of participating industry experts within the Broadband Forum. As opinions, the following information represents the current thoughts of experts, and not scientifically provable fact.

The following national broadband coverage is estimated based on the technology capabilities and costs for the year 2010, but the mature coverage would not be achieved until a few years after 2010. Note that the percentages stated below are cumulative. That is, the percentage coverage for a lower bit-rate includes the subscribers included for the high bit-rate cases for each case of serving architecture.

FTTH

The potential mature national population coverage for FTTH is estimated to provide at least 80 Mb/s downstream and 37 Mb/s upstream to approximately 15% of the population residing in single family dwellings. Fiber to multiple dwelling units is addressed under FTTC/B, although some multiple dwelling units are served by FTTH.

FTTC/B+FTTH

The potential mature national population coverage for FTTC/B plus FTTH is estimated to provide at least 80 Mb/s downstream and 37 Mb/s upstream to approximately 30% of population.

FTTN

The potential mature national population coverage for FTTN is estimated to provide the following using vectored VDSL2, with two-line bonding for only the longest lines:

-150 Mb/s downstream and 63 Mb/s upstream for at least 30% of population
-60 Mb/s downstream and 6 Mb/s upstream for 63% of population
-30 Mb/s downstream and 3 Mb/s upstream for 66% of population

Clearly, FTTH/C/B can provide bit-rates as high as or higher than FTTN using VDSL2. The FTTN bit-rates shown above reflect the capacity of the VDSL2 line.

[10] The data contained in the tables for VDSL2 and ADSL2plus using the same profile (see Note 4) are presented in a graphical and expanded format in Appendix A.

FTTSA with ADSL2plus
The potential mature national population coverage for FTTSA with ADSL2plus is estimated to provide the following using a single line for most subscribers and two-line bonding for a few:
-15 Mb/s downstream and 1 Mb/s upstream for 40% of population
-13 Mb/s downstream and 1 Mb/s upstream for 55% of population
-9 Mb/s downstream and 850 kb/s upstream for 70% of population
-6 Mb/s downstream and 800 kb/s upstream for 85% of population

Central Office
The potential mature national population coverage for the Central Office with a few remote serving nodes, using a single line only, is estimated to provide the following:
-13 Mb/s downstream and 1 Mb/s upstream for 30% of population
-9 Mb/s downstream and 850 kb/s upstream for 60% of population
-6 Mb/s downstream and 800 kb/s upstream for 80% of population
-700 kb/s downstream and 400 kb/s upstream for 92% of population

Radio (LTE, WiMAX, direct satellite)
Radio may provide lower bit rates to approximately 95% of the population, but radio may be poorly suited for sustained high bit rates.

While WiFi technology in combination with a suitable broadband link to the core network can provide sustained high bit rate service to a serving radius of a hundred meters, wide-area radio technologies such as WiMAX can cover a large area at a moderate cost provided that the cumulative data per subscriber is small. However, wide-area radio broadband access would be very expensive to deliver the Gigabytes per day that many triple-play subscribers would consume.

4.0 Conclusion

The cost to deploy and operate a broadband access network depends greatly on the local demographics, local geography, government policy, and the delivered bit-rate. These factors guide the choice of the best means to serve each area.

No single technology is the best way to serve all subscribers. FTTH/C/B will provide excellent broadband access in the areas where it is profitable for service providers to deploy the technology; it is estimated that that FTTH/C/B may ultimately reach 30% of living units in the United States. Broadband access to a large majority of subscribers in the United States will rely on hybrid fiber and DSL technology with FTTN providing 30 Mb/s and above (up to 150 Mb/s) coverage to approximately 66% of the population and CO/RT based technology providing between 13 Mb/s and 700 kb/s to approximately 92% of the population.

However, nearly ten percent of the population will only have access at very low bit rates or will only have one choice for broadband access[11]. This underserved segment mostly consists of the subscribers who are costly or difficult to serve. Consequently, subsidies could expand broadband access coverage to the greatest degree if the subsidies were applied for bit-rates between 13 Mb/s and 700 kb/s downstream and between 1 Mb/s and 400 kb/s upstream.

The Broadband Forum would welcome further discussion on these important issues and also ideas on further work the Forum could do, in regard to technical specifications or to white papers on broadband industry best practice.

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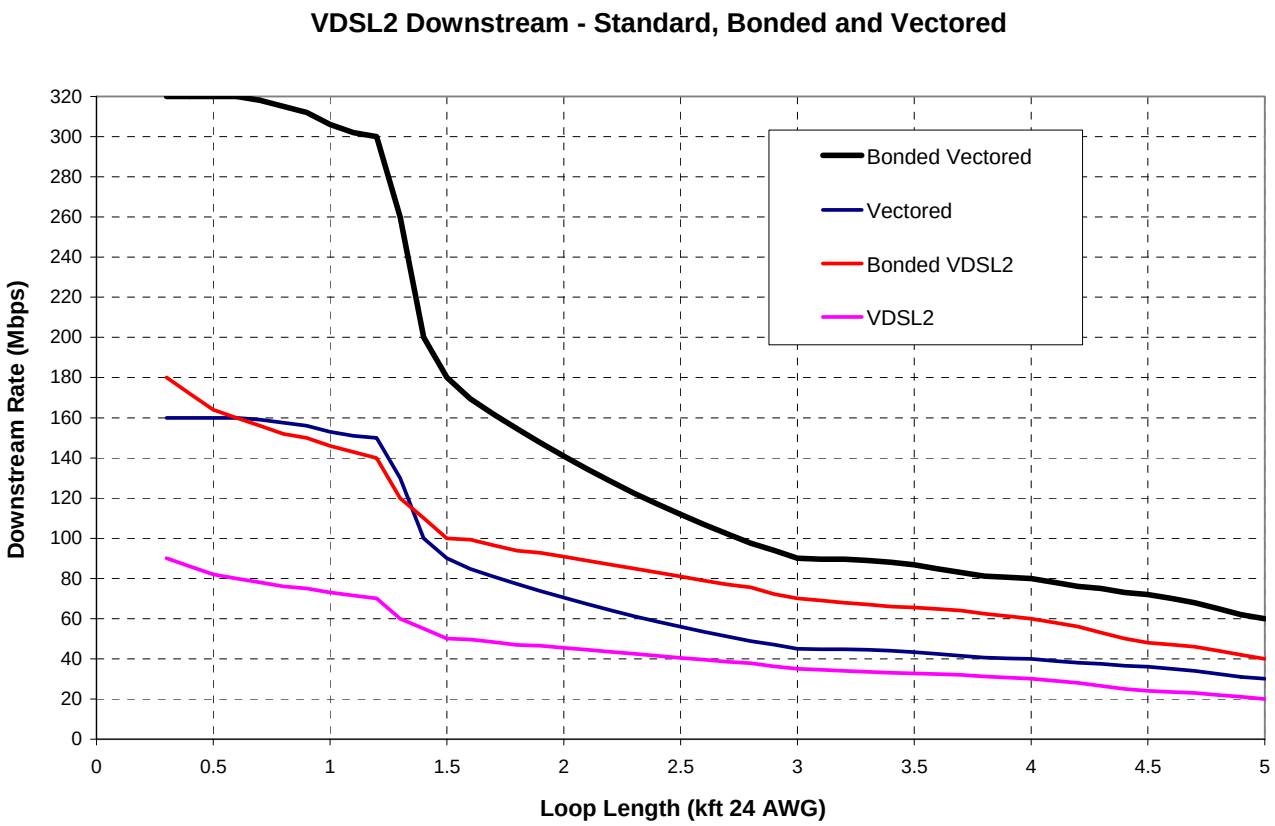
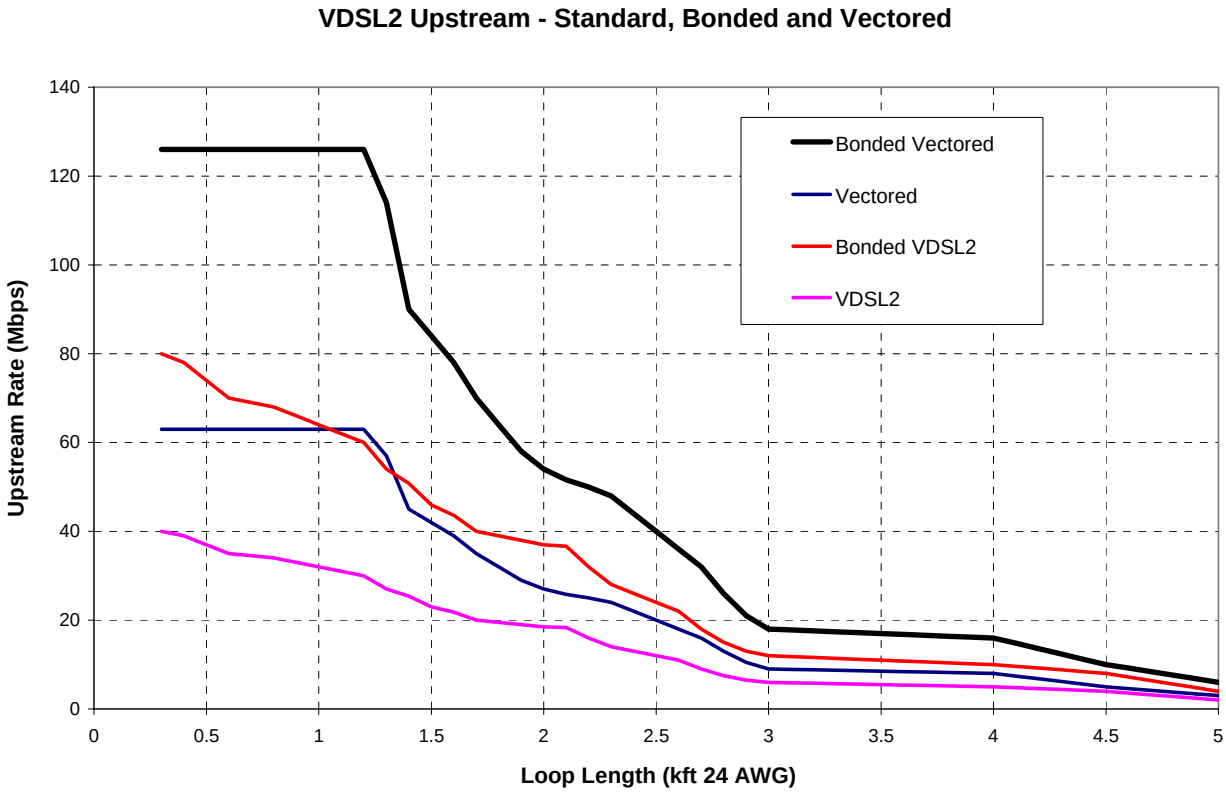
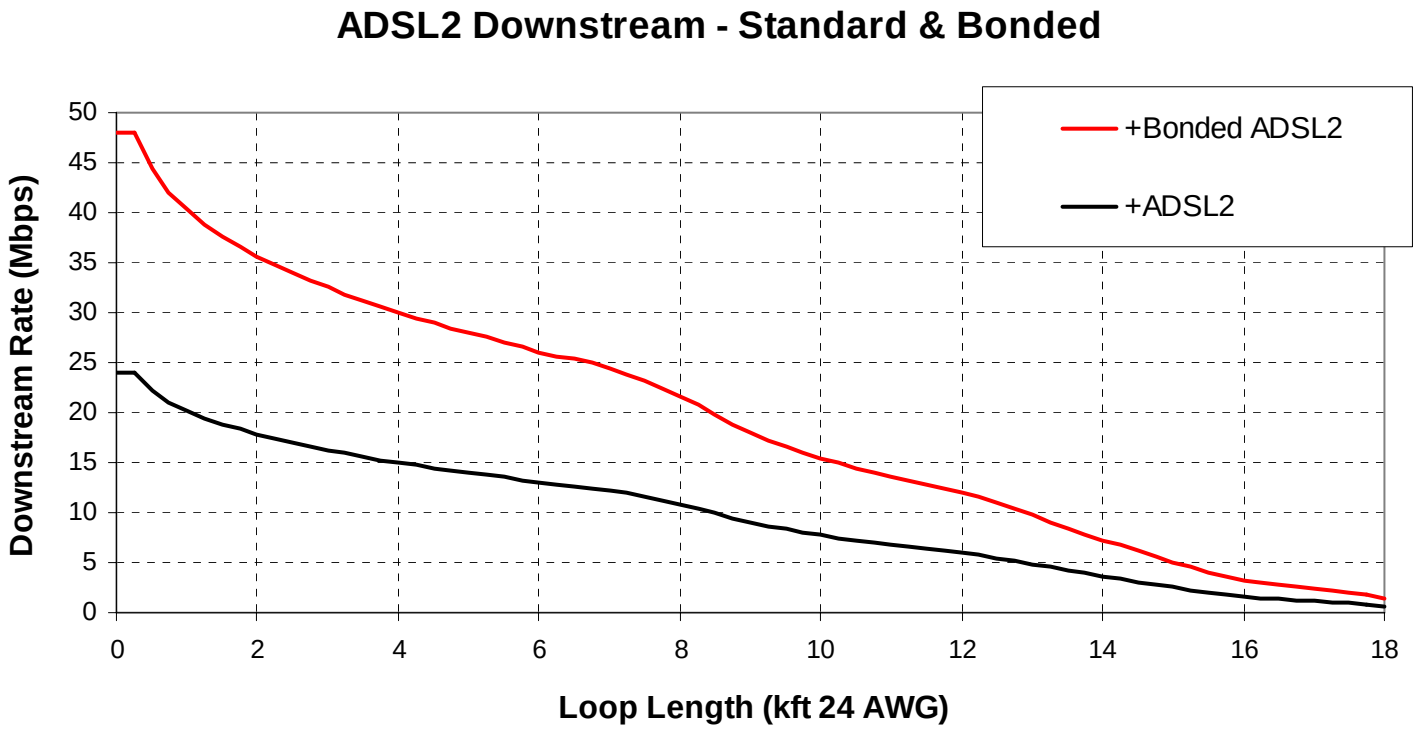
[11] This analysis has not considered use of SHDSL technology. While SHDSL was developed for business applications, SHDSL and bonded SHDSL may be considered for users on long loops to provide higher bit rates than identified above on longer loops. See BBF white paper “Symmetric DSL”, January 22, 2003. Since this white paper was published, SHDSL has been improved and bit rates are up to double the rates cited.

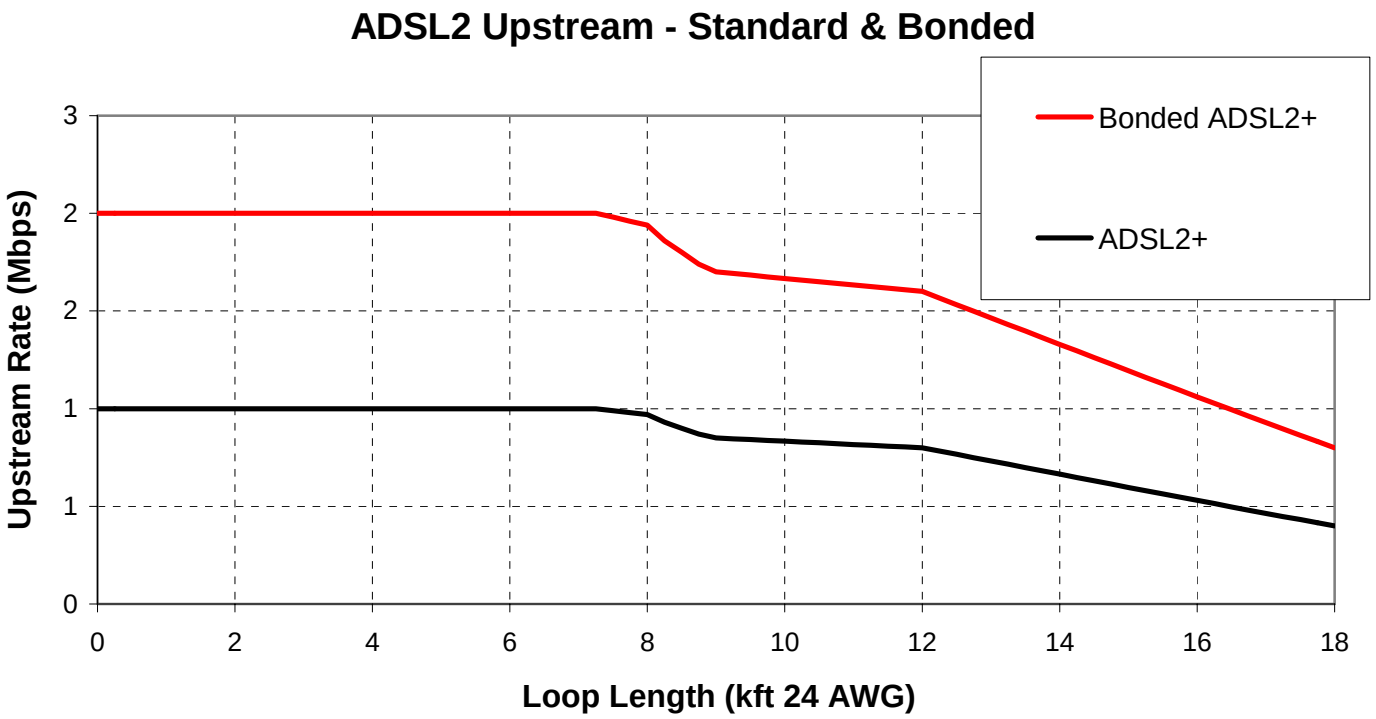
Appendix A


VDSL2 Downstream - Standard, Bonded and Vectored
Downstream Rate (Mbps)
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Loop Length (kft 24 AWG)
Bonded Vectored
Vectored
Bonded VDSL2
VDSL2


VDSL2 Upstream - Standard, Bonded and Vectored
Upstream Rate (Mbps)
Loop Length (kft 24 AWG)
Bonded Vectored
Vectored
Bonded VDSL2
VDSL2
0
20
40
60
80
100
120
140
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

	Downstream				Upstream			
	Vectored	VDSL2	Bonded Vectored	Bonded VDSL2	Vectored	VDSL2	Bonded Vectored	Bonded VDSL2
0.3	160000	90000	320000	180000	63000	40000	126000	80000
0.4	160000	86000	320000	172000	63000	39000	126000	78000
0.5	160000	82000	320000	164000	63000	37000	126000	74000
0.6	160000	80000	320000	160000	63000	35000	126000	70000
0.7	159000	78000	318000	156000	63000	34500	126000	69000
0.8	157500	76000	315000	152000	63000	34000	126000	68000
0.9	156000	75000	312000	150000	63000	33000	126000	66000
1	153000	73000	306000	146000	63000	32000	126000	64000
1.1	151000	71500	302000	143000	63000	31000	126000	62000
1.2	150000	70000	300000	140000	63000	30000	126000	60000
1.3	130000	60000	260000	120000	57000	27000	114000	54000
1.4	100000	55000	200000	110000	45000	25388	90000	50776
1.5	90000	50000	180000	100000	42000	22983	84000	45966
1.6	84706	49634	169413	99267	39000	21800	78000	43600
1.7	80891	48275	161783	96549	35000	20000	70000	40000
1.8	77249	46939	154497	93878	32000	19500	64000	39000
1.9	73776	46405	147551	92810	29000	19000	58000	38000
2	70449	45420	140898	90839	27000	18500	54000	37000
2.1	67245	44442	134491	88884	25800	18321	51600	36642
2.2	64184	43468	128368	86936	25000	16000	50000	32000
2.3	61276	42493	122552	84986	24000	14000	48000	28000
2.4	58523	41505	117045	83009	22000	13000	44000	26000
2.5	55914	40502	111828	81003	20000	12000	40000	24000
2.6	53434	39487	106867	78974	18000	11000	36000	22000
2.7	51053	38455	102106	76910	16000	9000	32000	18000
2.8	48753	37810	97505	75620	13000	7500	26000	15000
2.9	47000	36133	94000	72266	10500	6500	21000	13000
3	45000	35000	90000	70000	9000	6000	18000	12000
3.1	44775	34500	89550	69000	8900	5900	17800	11800
3.2	44765	34000	89530	68000	8800	5800	17600	11600
3.3	44510	33500	89019	67000	8700	5700	17400	11400
3.4	44052	33000	88105	66000	8600	5600	17200	11200
3.5	43387	32750	86774	65500	8500	5500	17000	11000
3.6	42405	32400	84809	64800	8400	5400	16800	10800
3.7	41468	32000	82936	64000	8300	5300	16600	10600
3.8	40581	31200	81161	62400	8200	5200	16400	10400
3.9	40250	30600	80500	61200	8100	5100	16200	10200
4	40000	30000	80000	60000	8000	5000	16000	10000
4.1	39000	29000	78000	58000	7400	4800	14800	9600
4.2	38000	28000	76000	56000	6800	4600	13600	9200
4.3	37500	26500	75000	53000	6200	4400	12400	8800
4.4	36500	25000	73000	50000	5600	4200	11200	8400
4.5	36000	24000	72000	48000	5000	4000	10000	8000
4.6	35000	23500	70000	47000	4600	3600	9200	7200
4.7	34000	23000	68000	46000	4200	3200	8400	6400
4.8	32500	22000	65000	44000	3800	2800	7600	5600
4.9	31000	21000	62000	42000	3400	2400	6800	4800
5	30000	20000	60000	40000	3000	2000	6000	4000


ADSL2 Downstream - Standard & Bonded
Downstream Rate (Mbps)
50
45
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
14
16
18
Loop Length (kft 24 AWG)
+Bonded ADSL2
+ADSL2


ADSL2 Upstream - Standard & Bonded
Bonded ADSL2+
ADSL2+
Upstream Rate (Mbps)
3
2
2
1
1
0
0
2
4
6
8
10
12
14
16
18
Loop Length (kft 24 AWG)

	Downstream ADSL2+		Upstream ADSL2+	
	ADSL2+	Bonded ADSL2+	ADSL2+	Bonded ADSL2+
0	24000	48000	1000	2000
0.25	23991	47982	1000	2000
0.5	22181	44362	1000	2000
0.75	21025	42050	1000	2000
1	20154	40308	1000	2000
1.25	19444	38887	1000	2000
1.5	18837	37674	1000	2000
1.75	18301	36602	1000	2000
2	17820	35640	1000	2000
2.25	17383	34765	1000	2000
2.5	16979	33959	1000	2000
2.75	16603	33207	1000	2000
3	16250	32501	1000	2000
3.25	15916	31832	1000	2000
3.5	15598	31195	1000	2000
3.75	15293	30586	1000	2000
4	15000	30000	1000	2000
4.25	14739	29478	1000	2000
4.5	14486	28971	1000	2000
4.75	14239	28478	1000	2000
5	13996	27992	1000	2000
5.25	13755	27509	1000	2000
5.5	13511	27022	1000	2000
5.75	13262	26523	1000	2000
6	13000	26000	1000	2000
6.25	12848	25695	1000	2000
6.5	12669	25337	1000	2000
6.75	12455	24911	1000	2000
7	12203	24405	1000	2000
7.25	11908	23816	1000	2000
7.5	11573	23146	990	1980
7.75	11203	22406	980	1960
8	10806	21611	970	1940
8.25	10391	20783	930	1860
8.5	9920	19841	900	1800
8.75	9432	18865	870	1740
9	9000	18000	850	1700
9.25	8638	17277	846	1692
9.5	8303	16606	842	1683
9.75	7998	15997	838	1675
10	7718	15436	833	1667
10.25	7468	14935	829	1658
10.5	7224	14449	825	1650
10.75	6991	13983	821	1642
11	6782	13564	817	1633
11.25	6583	13166	813	1625
11.5	6386	12771	808	1617
11.75	6194	12388	804	1608
12	6000	12000	800	1600
12.25	5808	11615	783	1566
12.5	5488	10976	766	1532
12.75	5168	10335	749	1498
13	4855	9710	732	1465
13.25	4547	9094	715	1431
13.5	4237	8474	698	1397
13.75	3931	7861	681	1363
14	3633	7266	665	1329
14.25	3351	6702	648	1295
14.5	3075	6150	631	1262
14.75	2805	5610	614	1228
15	2545	5090	597	1194
15.25	2291	4582	580	1161
15.5	2043	4085	564	1127
15.75	1800	3599	547	1094
16	1562	3124	530	1060
16.25	1462	2924	514	1027
16.5	1362	2724	497	994
16.75	1262	2524	481	961
17	1162	2324	464	929
17.25	1062	2124	448	896
17.5	962	1924	432	864
17.75	862	1724	416	832
18	700	1400	400	800